THE BRAIN

IN

HEALTH AND DISEASE.

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THE HISTOLOGY AND FUNCTIONS OF THE CEREBRUM.—The study of the histology and functions of the cerebrum—not alone of the several ganglionic centres, but also of the different layers of the great "hemispherical ganglia" formed by the convolutions of the cerebrum—has as yet been comparatively little prosecuted. It presents a wide field for investigation, experimental inquiry and discovery; and already, such investigators as Dr. Ferrier, Sir Charles Bell, Dr. Carpenter, and Dr. Brown-Séquard, have thrown great light upon the localization of brain function. We know very little, positively, of the different operations of psychological and intellectual life, the phenomena of which have been but slightly noticed, and are open to discussion. Mental diseases depend upon a physical lesion of the central nervous system; and as there is a very close relation existing between the regular functional activity of a normal brain and the diverse functional manifestations in insanity, the study of the structure and functions of the successive ganglia which compose the brain is a matter of deep interest as well as necessity to students of psychology.

The white substance of the hemispheres consists of medul-

lated nerve fibres of about 0.0026—0.0067 mm. in diameter; while at the surface of the larger ganglionic masses and towards the cortex, some non-medullated fibres are seen. The fibres of the white matter are separated from one another by bands of delicate connective tissue, fibrillated sustentacular matter, in which are situated, at intervals, round or oval nuclei, smooth in contour, and measuring 0.0093—0.0075 mm.

These fibres of the white matter may be divided very properly into two classes: 1st. Those having a radiating and converging direction or course; and 2d. Those uniting the two halves of the cerebrum and forming the corpus callosum, which is properly to be looked upon as a physiological as well as an anatomical commissure; and it is often found to be absent in congenital idiots. The cortex of the cerebrum, or grey matter of the convolutions, is divided into several layers or laminæ, the number being variously estimated by different observers, among whom are Kölliker, Arndt, Meynert and Frey. The latter regards the cortex as divisible into six laminæ. The general plan of structure of the grey matter of the cerebrum is primarily, a wide-meshed network of medullated fibres, in whose interstices ganglion cells are situated. We also find that very delicate network of very fine fibres met with in the grey matter of the spinal cord, first discovered by Deiters, which consist of very delicate fibrillæ springing from the broad protoplasm processes of the ganglion cell. These fibrillæ, Deiters regards as a system of secondary axis cylinders for the most delicate nerve fibres. Gerlach first described the network as occurring as well in the cortex of the cerebrum as in the spinal cord. The remainder of the grey matter is made up of the delicate sustentacular substance before alluded to as intervening between the fibres of the white matter. In the superficial layers of the convolutions, the cells are small, multipolar nerve cells, analogous to the small cells in the posterior cornua of the cord; while in the deeper stratum or fourth layer of Frey, are found large multipolar ganglion cells 0.025—0.040 mm. in diameter, presenting oval or roundish nuclei. These large cells correspond to the large cells in the anterior cornua of the spinal cord, which, it will be remembered, send out "axis

cylinder processes," which are prolonged into the nerve fibres of the motor roots. In like manner, we observe under the microscope an "axis cylinder process," given off from these multipolar ganglion cells of the deeper layers of the convolutions of the cerebrum, which process is prolonged into one of the nerve fibres of the corona radiata. It is, I think, demonstrable that there is a lateral anastomosis between the cells of each layer or laminæ and also anastomoses between the successive layers of the convolutions.

I desire now to advance the theory respecting the functions of the hemispherical ganglia or cortex of the cerebrum, which has appeared to me during my microscopical investigations on brain tissue, to be the most reasonable one. We are already familiar, through the admirable physiological treatises of the present day, with the general description of the structure and functions of the nervous system, so that in speaking of the structure and functions of the grey matter of the hemispherical convolutions, I desire to be understood as referring to the histological elements, the functional activities of which we are, as yet, comparatively unacquainted with. Of course it is impossible to limit exactly the special attributes of any particular group of cells in the convolutions of the cerebrum; yet, by comparing them with the elements of the spinal cord, may it not be possible to make certain legitimate inductions relative to their diverse activities? I have just stated that the large nerve cells of the convolutions correspond to the multipolar ganglion cells of the anterior cornua of the spinal cord, which cornua are connected with the motor roots of the spinal nerves; while the small and superficial cells of the convolutions are analogous to the small cells of the posterior cornua of the cord, which are connected with the sensory roots of the spinal nerves. We have also seen that in the multipolar ganglion cells of the deeper layers of the convolutions of the cerebrum, there exist processes which become the axis cylinders of nerve fibres. I think, therefore, that we may fairly conclude *that the superficial layers or laminæ of the convolutions of the hemispheres, disseminate the impression of general sensibility, and that the deeper layers containing the larger multipolar ganglion cells originate motor impulses.*

The cerebral ganglia whose structure and functions remain to be considered are the corpora quadrigemina, thalami optici, and corpora striata.

The structure of the corpora quadrigemina consists of a white layer overlaid with a zonal stratum of nerve fibres. Underneath them the crura cerebelli and corpora quadrigemina pass on to reach the cerebrum, and should more properly be called, as Frey remarks, crura cerebelli ad cerebrum. Laterally, there enter the corpora quadrigemina from below, the two lemnisci arising from the motor tract of the medulla oblongata, and traceable back to the same tract or part of the medulla. In the anterior tract of the corpora quadrigemina, a root of the optic nerve, coming from the corpus geniculatum internum terminates. Small nerve cells are seen in the internal grey substance of the quadrigeminal bodies, with larger multipolar and fusiform ganglion corpuscles, the latter being said by Meynert to be found in the deeper layers of the anterior bodies about the aqueduct of Sylvius. The functions of these bodies are tolerably well understood, as they give rise to the optic nerves and act as the ganglia of sight, from which they have been also called "optic ganglia." Destruction of these bodies cause complete blindness. They thus serve as nervous centres for the perception of light, and a reflex action also takes place through them, by which the amount of light admitted to the eye is regulated to accommodate the sensibility of the pupil. The structure of the optic thalami, like the corpora quadrigemina, consists of a white layer overlaid with a zone of nerve fibres. The posterior end of these ganglia has been termed the pulvinar.

Internally to it, and more posteriorly, is situated the corpus geniculatum internum; and, externally, the corpus geniculatum externum. Into the latter a portion of the optic tract passes on its way to the pulvinar. Fusiform cells are found, more deeply colored than those of the corpora quadrigemina. The cells of the corpus geniculatum externum are found to be frequently pigmented, and the internal geniculate body also contains fusiform cells.

The thalamus receives numerous white fasciculi coming from the hemispheres. They run towards the superior sur-

face of the thalamus to the superior and internal border and the pulvinar, and are ultimately lost in the same manner as are the fibres continued from the crus cerebri into the corpus striatum; that is, by a sub-division into close plexuses of extremely delicate nerve fibres. The functions of the optic thalami are but little understood. They are not, however, principally connected with vision. From experimental observations which have been made, I think it most probable that the optic thalami receive, preserve and transform the sensorial impressions previous to their definitive irradiation to the cortical periphery.

It would seem to be proper to regard the optic thalami in four distinct parts or ganglion tracts. (*a*) The anterior ganglion tract is undoubtedly connected with olfactive impressions. (*b*) The middle ganglion tract receives the nerve fibres of the second pair, and may properly be called the optic tract. (*c*) The posterior ganglion tract, from its connection with the perception of sounds, may be called the acoustic tract. And there is undoubtedly (*d*) another tract of the optic thalamus, which, from its close relation to the sensitive fibres of the convergent system, may be called the tract of general sensibility.

The structure of the corpora striata consists of a collection of grey matter, nerve cells, and of fine nerve fibres. They contain two larger nuclei, respecting which we know very little. The system of nerve fibres is derived from the crura cerebri running parallel in a straight direction, entering both nuclei, and ultimately lost in those nuclei. The surface of the corpora striata is grey, and in the grey matter we observe multipolar ganglion cells and smaller cells. The neuroglia is analogous to the neuroglia of the cortex of the cerebrum. There is also another set of fibres proceeding probably from the medullary substance of the hemispheres which ramify in the large nucleus of the corpus striatum. These fibres differ from those derived from the crus cerebri, which in this location are extremely attenuated, and present a plexiform arrangement. Physiologists have supposed the functions of the corpora striata to have some connection with sensation and volition, although they have not attempted to explain

the nature of the connection. As experimental observations have proved that destruction of the corpus striatum results in motor paralysis, with the preservation of intelligence depending upon the extent of the lesion; and also as cases have occurred in which the functions of the corpus striatum having been, not destroyed, but impaired, by compression or degeneration of its elements, there have resulted disturbances in the motor sphere, may we not reasonably infer that the corpora striata are undoubtedly the centres of the reception, regulation and elaboration of voluntary motor impressions emanating from the deep layers of the cortical matter, whose large cells originate them?

There is no question more interesting to the follower of mental pathology, than that of the connection between nerve function and nerve organization, and it is only by patient experiment and observation that we are to fully understand the nature of the relation between the histology of the brain and the physical functions. It is impossible to fully appreciate the pathological changes met with in the brain, until we are in full possession of all the available knowledge of cerebral histology and of the knowledge of the normal functional activity of nerve cells; and we certainly cannot understand defective intellect unless we are thoroughly acquainted with the ordinary and normal manifestations of intellect. We must, therefore, clearly understand the physiological laws of healthy mental action before we can comprehend any departure from the healthy working of such laws. With this end in view, have my efforts in the direction of the study of the physiology and pathology of the central nervous system been made.

It being a very difficult matter to harden the very delicate tissue of the brain, so as to be enabled to cut sufficiently thin sections for demonstrating the finer structural relation of the tissues, I give the formula which I use—and for which I am indebted to my friend, Prof. J. W. S. Arnold, of this city—for a hardening fluid for the brain and spinal cord, which, in its effects, surpasses any other hardening fluid, and better prepares the tissues for the reception of staining fluids. It is as follows:

Bi-chromate of ammonia.....160 grs.
Methyl alcohol.....10ℨ.
Distilled water.....30ℨ.—Mix.

The Pathology and Morbid Histology of Acute and Chronic Insanity.—The morbid histological changes occurring in insanity, are, at the present day, undergoing microscopical investigation at the hands of many very skillful observers, both in our own country and in Europe; and these changes assume great importance when we reflect upon the fact that the pathological phenomena discovered in the brains of persons dying insane, all have for their basis, interference with the due nutrition, growth and renovation of the brain cell, which, by interrupting the nutrition, stimulation and repose of the brain, essential to mental health, results in the impress of a pathological state in the brain and disordered mental function. The investigation of both the normal and the morbid histology of the brain is a work requiring labor, patience and perseverance, and also judgment in the recording of observations; and even with the most careful and conscientious microscopists, mistakes may be made at times, as to the nature and value of appearances met with in histological research.

We may fairly divide the pathological changes met with in insanity into three classes.

First. Those which may be considered accidental.

Second. Those which are found in other diseases, and yet appear to be concerned in the production of insanity.

Third. Those essential to mental disease.

In the *first* class, we may enumerate cerebral hæmorrhages, softening of the white substance, and disease of the cerebral vessels.

In the *second* class, we meet with thickening and opacity of the arachnoid, hyperæmia of the pia mater and of the brain, serous infiltration of the pia mater and collections of fluid in the arachnoid cavity.

In the *third* class, or the changes essential to mental disease, I would enumerate sub-arachnoid ecchymosis and a partial punctiform injection of the cortical substance with or without softening; extended softening of the middle portion of the cortical substance; adherence of the pia mater to the

surface of the brain; different discolorations of the cortical substance; loss of color of the cortical substance; atrophy of the convolutions; and lastly, induration of cerebral tissue. The naked eye appearances which may be met with in the bodies of those dying insane, are, chiefly, peculiarities in the form of the cranium, of which the most frequent is want of symmetry between the two sides; the shrunken and shrivelled ear in chronic insanity, consequent upon hæmatoma auris; variations from the normal standard in the thickness or thinness of the cranium, changes in the membranes as to appearance and structure; and finally, changes in the cerebral substance itself.

In *acute insanity*, the changes or prominent alterations in the brain met with by the writer have been—hyperæmic conditions of the brain and its membranes, which latter are often thickened and opaque; injection and softening of the cortical substance, and pigmentation of the cortical grey substance. While the dura mater is very rarely thickened, its vessels are found to be dilated and irregular, and the coats of the vessels much hypertrophied. The arachnoid I have found to be thickened, to be the seat of hæmorrhage, and have often found it covered with fine granulations on its surface. The blood-vessels of the brain I have found to present thickening of the coats, thickening of the sheath or hyaline membrane, deposits between the adventitia and sheath, and proliferation of nuclei. The neuroglia has been found to be the seat of various lesions in insanity, the principal of which are disseminated sclerosis and colloid degeneration. The cerebral cells I have found to be the seat of atrophy, pigmentary or granular degeneration, calcification and hypertrophy. Microscopical examination of the spinal cord in the insane has revealed, as a rule, very little.

The pathology of general paralysis, which is one of the most interesting forms of mental disorder, is very obscure and invites especial attention at the hands of the profession. I think that some of the principal changes occurring in paresis have their origin in a congestion originating in the ganglia of the sympathetic, transmitted along the spinal cord, ultimately involving every tissue within the cranium, and

eventuating simultaneously in the degeneration of blood-vessels, cells and nerve tubes, and in the mental and motor perversions which in so marked a manner distinguish general paralysis from all other diseases of the same class. The fundamental lesion of general paralysis is, I think, a general diffused interstitial encephalitis, which involves accessory structural changes of different character. The posterior columns of the cord are also not unfrequently affected. The primary and most palpable form of the interstitial degeneration is colloid, where the transformed matter is presented under the aspect of a hyaline substance, semi-transparent, slightly refractory, and at certain points of a bluish tint. When existing in isolated masses of small size, it preserves the form and aspect of whatever cerebral elements it may have invaded. This product of inflammation does not appear to be at all of a tubercular nature; neither is it fatty, being insoluble in ether or chloroform. It is not amyloid, because it is unaffected by tincture of iodine, solution of potash and soda, and is dissolved in strong acetic acid. It is not organic, as there is no reaction with hydrochloric acid. Its solubility in hot water, especially when potash or soda is added, would seem to indicate a peculiar chemical composition.

When we examine the cerebrum as the principal seat of paresis, we find the ependyma of the ventricles to be the centre, or perhaps one of many centres, of that destructive process which is indicated by the symptoms of general paralysis, which affects all parts of the encephalon, and produces those secondary pathological appearances which have previously been identified as the cause of the disorders of motility and sensibility which follow. The progress of the morbid degeneration from the point where the ventricles have become dilated, their ependyma thickened; where their surface, especially in the fourth ventricle, is covered with granulations, is probably upward along the connective tissue, involving all tissues as well, and is gradual and insidious, and can be traced only by means of the more advanced alterations in structure. This interstitial irritation, however, disseminated, is propagated by nuclear proliferation, and invades the white

matter in common with the cortical substance, and also the capillaries, which are thickened, tortuous and massed together. The cells of the cortical portion are sometimes found infiltrated with granulations, but retaining their form. This is found in the third stage of the disease. It is in the middle and inferior portions of the grey matter that the cells are observed to have brilliant nuclei tending towards colloid, while their normal aspect is preserved. The walls of the cell nearest the lesion are transformed into a shining, refractory hyaline substance, the colloid infiltration having been propagated to both.

The microscopic, as well as the naked eye appearance, may arise first in the brain, or they may appear first in the cord and medulla, and afterwards in the brain; and they may also show themselves simultaneously. If the brain be primarily attacked, the psychical signs predominate, or are exclusively manifested. If the medulla be the primary seat of the disease, muscular pain, tremor and ataxic symptoms, spreading gradually to the lips and tongue, and disturbance of the internal viscera corresponding to the portion of the spinal column involved precede alienation and increase the difficulty of diagnosis. Finally, when the whole cerebro-spinal axis participates at once in the colloid degeneration, the characteristic indications of paresis will appear simultaneously or in rapid succession. It is important to bear in mind that the colloid degeneration is sometimes absent, and that we may occasionally meet with it in brain disease, which is only remotely connected with paresis.

In chronic insanity, the changes chiefly met with in the brain, have been atrophy of the convolutions and brain itself, induration of both white and grey matter, thickening and opacity of the membranes, chronic hydrocephalus, effusions into the sub-arachnoid space, pigmentation of the cortical substance, and extended and profound sclerosis of the brain. The pia mater is found to be thickened and adhesive to the brain, and its vessels tortuous and thickened in their walls. I have also noticed atheromatous and fatty degeneration of the walls of the cerebral capillaries.

Having devoted considerable time to the microscopic in-

vestigation of both the normal and morbid histology of the brain, I desire to call particular attention to an appearance which I have noticed in the brains of those dying insane, and to which my attention has been drawn from the interest it assumes when viewed in the light of the probable ultimate cause of the nutritive defect which results in chronic insanity. We know, that for the proper nutrition and healthy functional activity of the brain-cell, the proper nutrient supply is required, and that we cannot have healthy mental function without a due supply of healthy blood to normal and healthy brain substance. We also know, if any agent operates in the influencing of the circulation unfavorably, so that a morbid condition of the cerebral capillaries be induced, that we shall inevitably have resulting, morbid changes, set up and maintained in the cerebral cells.

In previous writings on mental disorders, I have called attention to the fact that a microscopical examination of blood from insane patients as compared with an examination of blood from the same number of healthy persons, revealed in the blood of the insane a marked increase in the number of white blood corpuscles. In making microscopical examinations of brain tissue from chronic insanity, I have noticed repeatedly in different cases that have been presented to me for examination, lymphoid cells or white corpuscles, and also red corpuscles in small numbers in the membranes and in the substance of the brain itself, evidently having emigrated from the blood-vessels. From what I have observed, I think, that under conditions of inflammatory irritation of the brain, an emigration of lymphoid cells takes place on a large scale—the cells or corpuscles, by virtue of their vital contractility, passing through the walls of the vessels and penetrating into the brain tissue. It will be remembered that both Dr. Bastian and Dr. Blandford have noticed a plugging up of the blood-vessels by small embolic masses composed of aggregations of white corpuscles in insanity. Ecker found that the vessels of the grey matter were more generally dilated in insanity, and Ramier also noticed the same thing in the vessels of the pia mater, while Dr. Major has described a dilatation of the arteries in "brain wasting"—a condition which appertains to chronic insanity.

We have here, two factors which operate, I think, in the production of the appearance in the pia mater and the brain, of the lymphoid cells, and in some cases of the red corpuscles—first, the undue predominance and accumulation in the blood-vessels of the white corpuscles, which obstruct the capillaries, giving us as a result, an impeded circulation and an increased pressure in the coats of the vessels; and second, the dilatation of the vessels before alluded to. These two conditions are favorable to the rapid emigration of the white and also the red corpuscles through the walls of the vessels; and also, perhaps, the same condition may be produced at times by the obstruction in the capillary vessels becoming great enough to rupture them. Such lymphoid cells must act undoubtedly as foreign bodies, and a slow course of inflammation is set up. Such an inflammatory process must necessarily be of slight intensity and long duration, and these collections of lymphoid cells undoubtedly tend to become developed into a fibroid structure, resulting in the induration of the brain which we meet with in chronic insanity.

I am also forcibly impressed with the idea that we have here the solution of the problem as to the relation which exists between tuberculosis and insanity. Dr. Clonston, in the *Journal of Mental Sciences*, for April, 1863, showed, that of 828 patients who died with tubercular disease at the Royal Edinburgh Asylum, 153 passed rapidly into the state of chronic insanity, the acute stage being of very short duration, the patients all manifesting a decided tendency towards chronicity. He also noticed that the prognosis relating to mental recovery was eminently unfavorable, and that apparent recoveries proved to be only remissions. In these cases where the development of the two diseases seemed to Dr. Clonston to be nearly contemporaneous, was not the tuberculosis the result primarily of the escape or emigration of the lymphoid cells into the connective tissue of the lungs, owing to this state of leucocythæmia in the patient? I think that this condition occurs more frequently than we are aware of, especially in persons who inherit the predisposing neurotic element or morbific force. That there exists such an hereditary neurotic or morbific element or force, present in

both insanity and phthisis, I most firmly believe; and I also believe that there is a correllation of morbific force which renders these diseases mutually convertible. I have repeatedly seen this borne out by undeniable facts, children of one family being affected with both insanity and phthisis in many different instances.

To return, however, more immediately to our subject. Respecting the dilatation of the vessels, which I before alluded to, it appears to me that the general obstruction in the capillaries of the brain, causes, primarily, probably, a compensatory hyperæmia; and as this gradually becomes permanent, the small arteries would naturally become enlarged, as they have been found to be by Ecker and Dr. Major, and also myself, and their walls would become thickened, as we find them to be *post-mortem* in chronic insanity. Such long-continued mechanical hyperæmia causes an impairment of vitality and function, and this we find exemplified by the retrogressive changes which occur in the substance of the brain in chronic insanity—viz., atrophy, induration and degeneration of the nervous elements of the brain. With the exception of cases of apoplexy, in which large clots have been discovered *post-mortem*, I am not aware that any observer has described any such lymphoid deposit in the brain, which may or may not have undergone fibroid metamorphosis or degeneration. I think, therefore, that from both a physiological and pathological standpoint, these observations become of the highest clinical significance.

I desire not to be misapprehended as regarding the presence of the lymphoid deposits in the brain as the ultimate cause of insanity. I do, however, think, that by their presence we are enabled to explain many of the changes incident upon chronic insanity, and think their presence must affect very materially the ultimate molecular changes in the brain upon which its functional activity depends, and regard it as a very strong probability that such foreign deposits in the brain may, by interferring with the molecular changes just alluded to, destroy both functional excitability and activity. It would appear very probable that the prominent alterations taking place in chronic insanity—viz., atrophy of the convo-

lutions and of the brain itself, and induration of the two substances, with degeneration and atrophy of nerve cells—may be considered fairly to depend upon this abnormal state in the mutual relationship between the blood and the tissues, which becomes the ultimate cause of the nutritive defect which results in chronic insanity.